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Coronary Heart Disease Mortality Among Young Adults in the U.S. From 1980 Through 2002

Concealed Leveling of Mortality Rates

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Objectives The objective of our study was to examine age-specific mortality rates from coronary heart disease (CHD), particularly those among younger adults.

Background Trends for obesity, diabetes, blood pressure, and metabolic syndrome among young adults raise concerns about the mortality rates from CHD in this group.

Methods We used mortality data from 1980 to 2002 to calculate age-specific mortality rates from CHD for U.S. adults age ≥35 years.

Results Overall, the age-adjusted mortality rate decreased by 52% in men and 49% in women. Among women age 35 to 54 years, the estimated annual percentage change (EAPC) in mortality was −5.4% (95% confidence interval [CI] −5.8 to −4.9) from 1980 until 1989, −1.2% (95% CI −1.6 to −0.8) from 1989 until 2000, and 1.5% (95% CI −3.4 to 6.6) from 2000 until 2002. Among men age 35 to 54 years, the EAPC in mortality was −6.2% (95% CI −6.4 to −5.9) from 1980 until 1989, −2.3% (95% CI −2.6 to −2.1) from 1989 until 2000, and −0.5% (95% CI −3.7 to 2.9) from 2000 until 2002. Among women and men age ≥55 years, the estimated annual percentage decrease in mortality from CHD accelerated in more recent years compared with earlier periods.

Conclusions The mortality rates for CHD among younger adults may serve as a sentinel event. Unfavorable trends in several risk factors for CHD provide a likely explanation for the observed mortality rates. (J Am Coll Cardiol 2007;50:2128–32) © 2007 by the American College of Cardiology Foundation

In the U.S., mortality rates from coronary heart disease (CHD) have continued to decline steadily since 1968 (1). Nevertheless, CHD remains the leading cause of death and exacts a heavy social and economic toll. Improvements in population risk factors and in medical treatments of patients with CHD both contributed substantially to the declines seen between 1980 and 1990 (2).

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Concern had been expressed that the rate of decline in the age-adjusted mortality rate from CHD has slowed during the 1990s compared with the earlier decade (3). The trends in the age-adjusted mortality rate may conceal differences in the trends in the age-specific rates, which have received little attention. The particularly unfavorable trends in several risk factors for CHD among young adults raises the possibility that the trends in the mortality rates from CHD among younger adults declined less than those in older ones (4–9). Therefore, our objective was to examine the trends in the age-specific rates for CHD among U.S. adults from 1980 to 2002, particularly among younger adults.

Methods

Vital statistics data from the U.S. were used (10). We limited our analyses to people age 35 years or older. The underlying cause of death from CHD was determined using the International Classification of Diseases (ICD)-9 codes 410-414 and 429.2 for 1980 to 1998 and ICD-10 codes I20-I25 for 1999 to 2002. Population counts from the U.S. Census were used to calculate rates. We used census counts for the years 1980, 1990, and 2000 and intercensal estimates for the other years. Age adjustment was performed using the direct method to the estimated U.S. population of the year 2000 (11).

We used the software Joinpoint, version 3.0 (National Cancer Institute, Bethesda, Maryland), to examine changes in the annual percentage change in mortality rates from CHD

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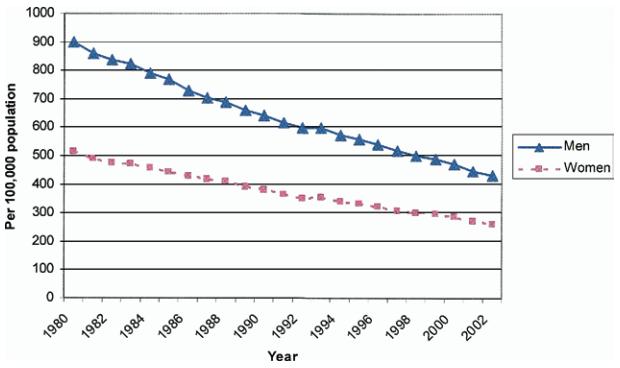

Figure 1 **Trends in Age-Adjusted Mortality Rates From Coronary Heart Disease**

Among both U.S. men and women age ≥35 years, the age-adjusted mortality rates from coronary heart disease have decreased steadily from 1980 through 2002.

(12). This software uses a Monte Carlo permutation test to identify points where the direction or magnitude of the trend changes and then fits the simplest model containing the fewest number of trend segments. We specified a maximum number of 3 joinpoints and assumed a Poisson distribution. For each segment, the software calculates the estimated annual percentage change (EAPC) and its 95% confidence interval (CI). In addition, the software tests whether the slope of each trend segment differs significantly from the segment immediately preceding it by using a *t* test.

Results

The overall age-adjusted mortality rate declined from 1980 through 2002 by 52% in men and by 49% in women (Fig. 1). The average annual rate of decline for men was 2.9% during the 1980s, decreasing to 2.6% during the 1990s, and for women, it was 2.6% decreasing to 2.4%. From 2000 through 2002, the average annual rate of decline was 4.4% for both men and women.

The age-adjusted rates concealed striking differences in the trends in age-specific rates (Tables 1 and 2, Fig. 2). When the overall time period was split into 2, the robust decrease in mortality rates that was observed for both men and women age 35 to 54 years during the period from 1980 to 1990 decelerated significantly for both genders during the period from 1991 to 2002. For those age ≥55 years, however, the rate of decrease was larger in the later period than the earlier one for both genders.

To provide a more nuanced examination of the data in each gender and age group, changes in the trend during the 23-year period were detected by Joinpoint regression modeling. Among women age 35 to 54 years, mortality decreased significantly by 5.4% from 1980 to 1989, slowed to an annual rate of decrease of 1.2%, and turned positive between 2000 and 2002, albeit with a wide CI that included 0%. Among men age 35 to 54 years, the mortality rate decreased by 6.2% per year from 1980 to 1989, slowed to 2.3% per year from 1989 to 2000, and leveled off between 2000 and 2002. Among women age ≥55 years, the EAPC was −1.5% between 1980 and 1999 and accelerated to −4.8% from 1999 until 2002. Among men age ≥55 years, the EAPC was −2.6% between 1980 and 1990, slowed to 1.9% from 1990 to 1996, and accelerated to −3.7% from 1996 until 2002.

Abbreviations and Acronyms

CHD = coronary heart disease
CI = confidence interval
EAPC = estimated annual percentage change
ICD = International Classification of Diseases

Discussion

The trends for mortality from CHD among U.S. adults age 35 to 54 years are disquieting. The EAPC slowed markedly from 1980 to 2002 in both men and women. Particularly noteworthy is that the mortality rate among women age 35 to 44 years has been increasing on average by 1.3% (95% CI 0.2 to 2.5) per year since 1997.

Changes in mortality rates generally reflect changes in incidence and case-fatality rate (13). Unfortunately, solid data about incidence of CHD in the U.S. are not readily available. Many studies use hospitalization rates as a rather unsatisfactory proxy that can be difficult to interpret (14). Thus, data from the Worcester Heart study and Olmsted County both reported decreases in incidence from the late 1970s into the late 1980s (15,16). Data from the Nurses' Health study from 1980 to 1994 also reported a reduction in the incidence of CHD among participants age 34 to 59 years (17). Conversely, an analysis of data from the Atherosclerosis Risk in Communities study reported an increase in the incidence of hospitalizations for myocardial infarction between 1987 and 1994 among residents age 35 to 74 years (18). A subsequent analysis of the data from this same study showed a decrease in the hospitalization rate of non–ST-segment elevation acute coronary syndrome between 1987 and 1994 (19). Among women living in Olmsted County, the incidence of CHD appeared to have increased during the early 1990s (16). An analysis of data from the National Health and Nutrition Examination Survey I Epidemiologic

Table 1 **EAPC in Unadjusted Mortality Rates From Coronary Heart Disease Among U.S. Adults Age ≥35 Years, 1980 to 2002**

	1980 to 1990		1991 to 2002	
	EAPC	95% CI	EAPC	95% CI
Age 35–54 yrs				
Men	−6.0	−6.2 to −5.8	−2.1	−2.4 to −1.8
Women	−5.2	−5.5 to −5.0	−0.9	−1.4 to −0.5
Age ≥55 yrs				
Men	−2.6	−2.7 to −2.4	−2.9	−3.3 to −2.5
Women	−1.5	−1.7 to −1.3	−2.3	−2.7 to −1.8

CI = confidence interval; EAPC = estimated annual percentage change.

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Table 2 EAPC in Age-Specific Mortality Rates From Coronary Heart Disease Among U.S. Adults Age ≥35 Years, 1980 to 2002

	Period 1		Period 2		Period 3	
Gender and Age (yrs)	Years	EAPC (95% CI)	Years	EAPC (95% CI)	Years	EAPC (95% CI)
Men						
35–54	1980 to 1989	−6.2 (−6.4 to −5.9)	1989 to 2000	−2.3* (−2.6 to −2.1)	2000 to 2002	−0.5 (−3.7 to 2.9)
≥55	1980 to 1990	−2.6 (−2.8 to −2.4)	1990 to 1996	−1.9* (−2.5 to −1.3)	1996 to 2002	−3.7* (−4.2 to −3.3)
Women						
35–54	1980 to 1989	−5.4 (−5.8 to −4.9)	1989 to 2000	−1.2* (−1.6 to −0.8)	2000 to 2002	1.5 (−3.4 to 6.6)
≥55	1980 to 1999	−1.5 (−1.6 to −1.4)	1999 to 2002	−4.8* (−6.6 to −3.0)		

*EAPC is significantly different from slope in antecedent period ($p < 0.05$).
Abbreviations as in Table 1.

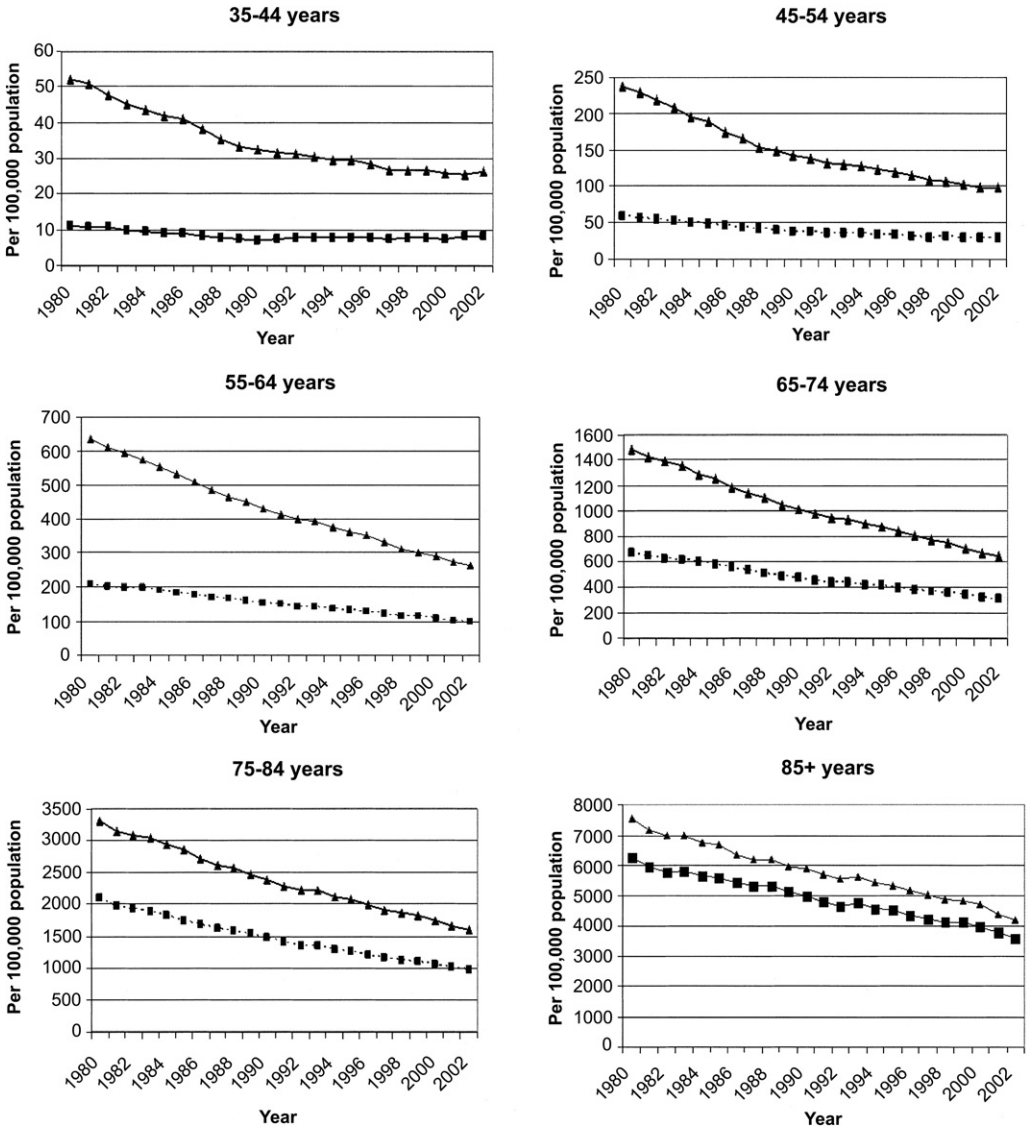

Figure 2 Trends in Age-Specific Mortality Rates From Coronary Heart Disease

Among adults age 35 to 44 years, the mortality rate from coronary heart disease changed little among women **(squares)** since the late 1980s and showed evidence of leveling off in more recent years among men **(triangles)**. Among adults age 45 to 54 years, the rate of decline in the mortality rate from coronary heart disease slowed around 1990 in both men and women.

Follow-up study suggested that both reductions in incidence and case-fatality rates contributed to the decline in cardiovascular disease between 1971 and 1992, as in other industrialized countries (20). Data from the Framingham Heart study showed declines in mortality from sudden cardiac death and nonsudden CHD between 1950 and 1999, suggesting that both primary and secondary prevention contributed to the declines (21). Reductions in the case-fatality rate for CHD have been reported consistently (15,16,18,19,22–25).

Unfortunately, data concerning the incidence and case-fatality rates of CHD among young adults are not readily available. However, the unfavorable trends during the 1990s in mortality rates from CHD among young adults coincided with a substantial deterioration in several risk factors for CHD. Considerable increases in abdominal obesity, diabetes, and hypertension in younger adults (4,5,8,9) have been compounded by stasis in cholesterol concentrations (6,7).

The increases in the prevalence of obesity and diabetes in the U.S. since 1976 to 1980 (26–28) and the increases in the prevalence of the metabolic syndrome and hypertension during the 1990s (5,8) are potential warning signs that the hard-fought gains in mortality improvements might be arrested or even reversed. In addition, the decline in concentrations of total cholesterol slowed during the 1990s, even as the use of cholesterol-lowering medications escalated (6,7). However, the prevalence of smoking continues to decline (29), and a slight decrease in the proportion of U.S. adults who are totally sedentary during leisure time has also occurred during the late 1990s (30). As a result of the conflicting trends in the various risk factors, the risk of CHD as determined by the National Cholesterol Education Program risk score for CHD has not changed (31).

The adverse mortality trends in young adults have occurred despite the increasingly wide use of evidence-based therapies such as angioplasty, thrombolysis, angiotensin-converting enzyme inhibitors, statins, and antiplatelet agents. This suggests that a vigorous public health response is needed to address lifestyle behaviors. Efforts to accelerate the past declines in smoking must be continued. Increased efforts to improve diet are now urgently required (32,33). Policy change at the national and state levels potentially offers the most effective and cost-effective interventions (33,34). To prevent obesity, energy intake must be less than energy expenditure. For many, messages of caloric restriction and increased physical activity, therefore, need to be amplified. Clinicians should also be aware of the unfavorable trends in coronary heart disease among younger adults in recent years and vigorously screen for risk factors for cardiovascular disease as recommended by guidelines and provide counsel about appropriate lifestyle behaviors. For patients found to have 1 or more risk factors, clinicians should optimally manage these risk factors according to prevailing guidelines.

Timely actions could potentially transform the abhorrent risk factor profile that currently characterizes much of the U.S. population and counteract the adverse trends that are now killing younger adults. Complacency runs a high risk: mortality rates among younger adults may represent the leading edge of a brewing storm.

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REFERENCES

1. National Institutes for Health, National Heart, Lung, and Blood Institute. Morbidity and Mortality: 2007 Chartbook on Cardiovascular, Lung, and Blood Diseases. Available at: http://www.nhlbi.nih.gov/resources/docs/07_chtbk.pdf. Accessed October 15, 2007.
2. Hunink MG, Goldman L, Tosteson AN, et al. The recent decline in mortality from coronary heart disease, 1980–1990. The effect of secular trends in risk factors and treatment. JAMA 1997;277:535–42.
3. Cooper R, Cutler J, Desvigne-Nickens P, et al. Trends and disparities in coronary heart disease, stroke, and other cardiovascular diseases in the United States: findings of the National Conference on Cardiovascular Disease Prevention. Circulation 2000;102:3137–47.
4. Ford ES, Mokdad AH, Giles WH. Trends in waist circumference among U.S. adults. Obes Res 2003;11:1223–31.
5. Ford ES, Giles WH, Mokdad AH. Increasing prevalence of the metabolic syndrome among U.S. adults. Diabetes Care 2004;27:2444–9.
6. Ford ES, Mokdad AH, Giles WH, Mensah GA. Serum total cholesterol concentrations and awareness, treatment, and control of hypercholesterolemia among US adults: findings from the National Health and Nutrition Examination Survey, 1999–2000. Circulation 2003;107:2185–9.
7. Carroll MD, Lacher DA, Sorlie PD, et al. Trends in serum lipids and lipoproteins of adults, 1960–2002. JAMA 2005;294:1773–81.
8. Hajjar I, Kotchen TA. Trends in prevalence, awareness, treatment, and control of hypertension in the United States, 1988–2000. JAMA 2003;290:199–206.
9. Centers for Disease Control and Prevention. Prevalence of diabetes and impaired fasting glucose in adults—United States, 1999–2000. MMWR Morb Mortal Wkly Rep 2003;52:833–7.
10. Centers for Disease Control and Prevention. Compressed Mortality File. Underlying Cause-of-Death. Available at: http://wonder.cdc.gov/mortSQL.html. Accessed May 9, 2006.
11. Klein RJ, Schoenborn CA. Age adjustment using the 2000 projected U.S. population. Healthy People 2010 Statistical Notes, No. 20, 2001. Available at: http://0-www.cdc.gov.mill1.sjlibrary.org/nchs/data/statnt/statnt20.pdf. Accessed October 15, 2007.
12. Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. Stat Med 2000;19:335–51.
13. Tunstall-Pedoe H, Kuulasmaa K, Mahonen M, Tolonen H, Ruokokoski E, Amouyel P. Contribution of trends in survival and coronary-event rates to changes in coronary heart disease mortality: 10-year results from 37 WHO MONICA project populations. Monitoring trends and determinants in cardiovascular disease. Lancet 1999;353:1547–57.
14. Pearson TA. The epidemiologic basis for population-wide cholesterol reduction in the primary prevention of coronary artery disease. Am J Cardiol 2004;94:4F–8F.
15. Goldberg RJ, Yarzebski J, Lessard D, Gore JM. A two-decades (1975 to 1995) long experience in the incidence, in-hospital and long-term case-fatality rates of acute myocardial infarction: a community-wide perspective. J Am Coll Cardiol 1999;33:1533–9.
16. Roger VL, Jacobsen SJ, Weston SA, et al. Trends in the incidence and survival of patients with hospitalized myocardial infarction, Olmsted County, Minnesota, 1979 to 1994. Ann Intern Med 2002;136:341–8.
17. Hu FB, Stampfer MJ, Manson JE, et al. Trends in the incidence of coronary heart disease and changes in diet and lifestyle in women. N Engl J Med 2000;343:530–7.
18. Rosamond WD, Chambless LE, Folsom AR, et al. Trends in the incidence of myocardial infarction and in mortality due to coronary heart disease, 1987 to 1994. N Engl J Med 1998;339:861–7.
19. Watkins S, Thiemann D, Coresh J, Powe N, Folsom AR, Rosamond W. Fourteen-year (1987 to 2000) trends in the attack rates of, therapy

for, and mortality from non–ST-elevation acute coronary syndromes in four United States communities. Am J Cardiol 2005;96:1349–55.
20. Ergin A, Muntner P, Sherwin R, He J. Secular trends in cardiovascular disease mortality, incidence, and case fatality rates in adults in the United States. Am J Med 2004;117:219–27.
21. Fox CS, Evans JC, Larson MG, Kannel WB, Levy D. Temporal trends in coronary heart disease mortality and sudden cardiac death from 1950 to 1999: the Framingham Heart Study. Circulation 2004;110:522–7.
22. Burke GL, Sprafka JM, Folsom AR, Luepker RV, Norsted SW, Blackburn H. Trends in CHD mortality, morbidity and risk factor levels from 1960 to 1986: the Minnesota Heart Survey. Int J Epidemiol 1989;18 Suppl 1:S73–81.
23. Derby CA, Lapane KL, Feldman HA, Carleton RA. Sex-specific trends in validated coronary heart disease rates in southeastern New England, 1980–1991. Am J Epidemiol 2000;151:417–29.
24. McGovern PG, Jacobs DR Jr., Shahar E, et al. Trends in acute coronary heart disease mortality, morbidity, and medical care from 1985 through 1997: the Minnesota Heart Survey. Circulation 2001; 104:19–24.
25. Yarzebski J, Bujor CF, Lessard D, Gore JM, Goldberg RJ. Recent and temporal trends (1975 to 1999) in the treatment, hospital, and long-term outcomes of Hispanic and non-Hispanic white patients hospitalized with acute myocardial infarction: a population-based perspective. Am Heart J 2004;147:690–7.
26. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999–2000. JAMA 2002;288: 1723–7.
27. Harris MI, Hadden WC, Knowler WC, Bennett PH. Prevalence of diabetes and impaired glucose tolerance and plasma glucose levels in U.S. population aged 20–74 years. Diabetes 1987;36:523–34.
28. Harris MI, Flegal KM, Cowie CC, et al. Prevalence of diabetes, impaired fasting glucose, and impaired glucose tolerance in U.S. adults. The Third National Health and Nutrition Examination Survey, 1988–1994. Diabetes Care 1998;21:518–24.
29. Centers for Disease Control and Prevention. Percentage of adults who were current, former, or never smokers, overall and by sex, race, Hispanic origin, age, education, and poverty status. National Health Interview Surveys, Selected Years—United States, 1965–2004. Available at: http://www.cdc.gov/tobacco/data_statistics/tables/adult/table_2.htm. Accessed October 15, 2007.
30. Centers for Disease Control and Prevention. Prevalence of no leisure-time physical activity—35 states and the District of Columbia, 1988–2002. MMWR Morb Mortal Wkly Rep 2004;53:82–6.
31. Ajani UA, Ford ES. Has the risk for coronary heart disease changed among US adults? J Am Coll Cardiol 2006;48:1177–82.
32. Havas S, Roccella EJ, Lenfant C. Reducing the public health burden from elevated blood pressure levels in the United States by lowering intake of dietary sodium. Am J Public Health 2004;94: 19–22.
33. U.S. Department of Health and Human Services. A Public Health Action Plan to Prevent Heart Disease and Stroke. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2003.
34. Unal B, Critchley JA, Capewell S. Modelling the decline in coronary heart disease deaths in England and Wales, 1981–2000: comparing contributions from primary prevention and secondary prevention. BMJ 2005;331:614–7.

APPENDIX

For the annual percent changes in mortality rates from CHD among U.S. adults age ≥35 years by gender and age group, please see the online version of this article.